open standard for IBOC. I wholeheartedly agree with this position; however, even if this matter is resolved in some satisfactory fashion, there remain serious problems with the implementation of NRSC-5.

Adoption of NRSC-5 Would Thwart Spectrum Planning for All-Digital Operations

In its 2002 Report and Order, the Commission declined to endorse the iBiquity all-digital AM and FM IBOC systems, stating that "it would be premature to endorse systems that have not been subject to comprehensive and impartial testing. Moreover, adoption of an all-digital standard requires the consideration of novel and more complex technical and policy issues that arise only when the constraints of 'designing around' the legacy analog transmission standard are eliminated".[3] This is exactly right. Take, for example, the iBiquity all-digital system for the AM band. This system has a nominal bandwidth of 20 kHz and was designed for groundwave service only. Not only does it not support skywave service, but it appears that it would perform badly in situations where a station's nighttime groundwave coverage is subject to self-interference from skywave. Are these the correct design decisions for the future use of the AM band? In this brave new digital era, do we really want to write off the unique capability of this band to provide wide area coverage extension at night for selected stations? And do we really want to continue to suffer coverage restrictions due to first adjacent channel skywave interference by transmitting a 20 kHz bandwidth emission, when advances in audio codec technology would permit adequate quality to be achieved with a nominal bandwidth of only 10 kHz? And do we not want to seize the opportunity to finally deal with the nagging problem of skywave self-

[3] *First Report and Order in the Matter of Digital Audio Broadcasting Systems and Their Impact on the Terrestrial Radio Broadcast Service*, October 10, 2002, at 37.

interference? These are clearly matters that require *much* more study and consideration before the fateful step is taken to adopt an all-digital standard.

But here is the problem: if the Commission adopts the hybrid IBOC systems specified in NRSC-5, then the die is already cast. Receivers designed to work with the hybrid systems will work only with the all-digital systems specified in NRSC-5, and none other. If and when we reach a point of critical mass where the market penetration of digital receivers permits stations to begin transitioning to all-digital operation, then there is really no choice but to use the all-digital systems that were specified in NRSC-5 when that standard was first adopted. Otherwise, existing receivers will no longer function after the transition. The conclusion should be clear: NRSC-5 cannot be adopted, in whole or in part, until the requisite studies of the policy and technical issues referred to above have taken place.

Nighttime AM IBOC Requires Further Study, Not Blanket Authorization

In the 2002 Report and Order, the Commission stated as a policy goal, "we favor the rapid implementation of DAB in a manner that will not disrupt existing service".[4] Although it was recognized that this goal was unattainable in absolute terms, the tradeoffs involved were considered to be acceptable. With regard to the AM system, it was put this way: "the potential benefits of digital AM IBOC far outweigh the small possible increase in interference"[5]. In my previous comments[6], I provided some analysis showing how the interference from the AM hybrid system can in no sense be considered "small". If this is not sufficently convincing, I refer you to the other commenters who have provided real

[4] *Id.* at 7.
[5] *Id.* at 24.
[6] Comments of Barry D. McLarnon, filed July 14, 2005.

world examples of the interference. Considering the relatively small number of AM stations actually using IBOC to date, and the daytime nature of the emissions thus far, these reports are merely the tip of the iceberg. Most of these reports concern IBOC interference from second, and sometimes third, adjacent channel stations, which are the major source of daytime problems. At night, skywave IBOC interference from first adjacent stations will be the additional problem that is far from "small".

It should be clear, even in these early days of deployment of the AM hybrid system, that the interference problems were understated by iBiquity and the NRSC, and the tradeoffs are not as promised. This being the case, the Commission should not grant the blanket authorization for nighttime operation of this system that is being requested by iBiquity and its supporters. It is equally clear, however, that the full extent of the nighttime interference problem will not be appreciated by all concerned until nighttime tests have been conducted by a sufficient number of stations. It is therefore suggested that full time AM IBOC operation be authorized for a limited period of time. This test period should be well publicized, and all stations should be encouraged to take this opportunity to assess the impact, if any, of adjacent channel IBOC signals on their coverage. All stations transmitting IBOC should be required to maintain a log of their digital transmission periods and power levels so that they can be correlated with interference reports. Alternating several periods of IBOC and non-IBOC nighttime operation may facilitate the comparison. An attempt should also be made to alert the general public that these tests are taking place.

After these tests have been conducted, the Commission could open a comment window and study the results, with a view towards determining what changes in usage of the AM band would really serve the public interest. Of course, no nighttime IBOC

operations should take place without the prior approval of the other countries who are signatory to the international agreements dealing with AM broadcasting in the Americas, and these countries should be encouraged to take part in the evaluation of the system and subsequent studies.

Respectfully submitted,

Barry D. McLarnon, P.E.
2696 Regina Street
Ottawa, ON K2B 6Y1
Canada

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of:	)	
	)	
Digital Audio Broadcasting Systems	)	MM Docket No. 99-325
And Their Impact on the Terrestrial	)	
Radio Broadcast Service	)	

Reply Comments of David L. Hershberger on National Radio Systems Committee's "In-Band/On-Channel Digital Radio Broadcasting Standard NRSC-5"

The comments of Microsoft Corporation, Broadcast Signal Lab, LLP, and Impulse Radio correctly point out that NRSC-5 represents an archaic form of standardization. I wish to heartily endorse the views of Microsoft et. al., but I also wish to point out in these reply comments that the notion suggested by Microsoft should be expanded.

Microsoft suggests that the audio codec used for digital audio broadcasting should be upgradeable. I would add to this that the modulation method should also be upgradeable. In other words, digital radio broadcasting should be done with a purely software defined radio (SDR) approach, and not the restrictive, secretive, and monopolistic proposal at hand.

NRSC-5 proposes to standardize the transmitted signal. This is archaic, vacuum-tube era thinking. Today, general-purpose digital signal processors are used to decode digital radio signals, and in some cases, analog signals. These processors are reprogrammable. It would be much better to instead *standardize the receiver*. The receiver should be characterized in terms of its instruction set, RAM, NVRAM, clock speed, etc., and a secure over-the-air programming method. Then, broadcasters may choose a modulation method and audio codec, which best suits their needs. This approach would not become prematurely obsolete the way NRSC-5 most certainly will.

NRSC-5 is archaic because it proposes to standardize the transmitted signal. For all time, the standard will be limited to just one audio encoder and just one modulation method (although there may be some minor variations in each). This has already proven to be a shortsighted concept in Europe where Eureka 147 DAB has been deployed. The audio codec (MPEG-2) is already obsolete, by several generations. If the audio codec were upgradeable, multicasting could be significantly increased.

At the 1997 IEEE Broadcast Technology Symposium, I presented a paper detailing how a SDR approach to digital radio broadcasting might be implemented. That paper is included with these reply comments. (Please note that I am no longer employed by

Continental Electronics, as I was when the paper was presented.) There are many ways to implement SDR, and the purpose of the paper is to give an example.

This paper was written in 1997 just as DRM committee work was beginning. Now that DRM is being deployed, I would suggest that one of the most robust DRM transmission modes could be used as the method for transmitting demodulation software to SDR receivers, rather than the "straw man" in the 1997 paper.

Most of these reply comments concern the AM system but they are also generally applicable to the FM system.

NRSC-5 is fatally flawed for the following reasons:

Excessive bandwidth and interference

NRSC-5 occupies three channels rather than one, causing adjacent channel interference on a wide scale, particularly in the AM system. The AM signal format is incompatible with the allocation structure, especially at night. To support the comments I made in this proceeding in June 2004, I had posted short MP3 files (slightly less than three minutes) showing what the interference sounded like during the March 2004 nighttime IBOC tests at KXNT in Las Vegas on 840 kHz, which interferes with reception of our local 5 kilowatt AM station on 830 kHz (KCNO, Grass Valley, CA). Those recordings are still available online. This file was recorded on March 3, 2004, shortly after 10 PM local time:

http://www.w9gr.com/kncoiboc.mp3

This file was recorded several days earlier (February 23, 2004) when KXNT was not testing IBOC, also shortly after 10 PM local time:

http://www.w9gr.com/knco.mp3

These recordings were made 6.4 miles from the KNCO transmitter and 384 miles from the KXNT transmitter. For more details on the receiver, directional antenna patterns, etc., please refer to my June 2004 comments.

I believe that KXNT's STA for nighttime IBOC testing expired June 20, 2004. Yet I have heard nighttime IBOC transmissions from KXNT on many occasions between sunset and about midnight local time when I have tried to listen to KNCO, apparently because KXNT sometimes forgets to turn off IBOC at night. Here is a partial list of dates on which I have heard nighttime IBOC interference from KXNT:

July 18, 2004	*August 21, 2004*	*June 21, 2005*
July 19, 2004	August 22, 2004	June 26, 2005
July 20, 2004	September 20, 2004	June 29, 2005
July 24, 2004	September 21, 2004	July 6, 2005
July 29, 2004	January 23, 2005	July 15, 2005
August 4, 2004	March 5, 2005	July 16, 2005
August 11, 2004	March 6, 2005	August 6, 2005
August 12, 2004	March 20, 2005	
August 15, 2004	June 4, 2005	

In these cases I have heard strong noise-type interference affecting only KNCO's lower sideband, and affecting only KOA's upper sideband on 850 kHz. Therefore, the interference is originating from an IBOC transmitter whose analog signal is on 840 kHz, and which is transmitting IBOC interference sidebands from 825-830 and 850-855 kHz.

This is just one example of wide scale interference to local reception that will occur if NRSC-5 is approved for nighttime operation on AM. I would expect the interference to be considerably worse in the eastern half of the country where stations are packed more closely together.

The analog and digital signal arrangement is inappropriate

The NRSC-5 proposal places the digital signals where they create the maximum possible interference to adjacent channel analog signals. The analog signal is on the station's assigned frequency, while the digital sidebands occupy both adjacent channels, creating demodulated interference in a 0-5 kHz bandwidth.

There are at least three possible solutions to this problem:

1. Move the digital sidebands away from the carrier frequencies of adjacent channels. The digital sidebands as proposed occupy ± 10 to ± 15 kHz. For example, if the digital sidebands occupied ± 2.5 to ± 7.5 kHz, then the interference generated would be above 2.5 kHz and out of the bandpass of AM radios claimed by the proponents of NRSC-5. In wider bandwidth radios, the digital sidebands would interfere with the originating station rather than "innocent bystander" adjacent channel licensees.

2. Swap the analog and digital signals. For example, for an AM station assigned to 840 kHz, the digital signal would be centered on 840 kHz, occupying 835-845 kHz. Two analog signals would be transmitted at lower power on 830 and 850 kHz. For spectral control, and to minimize interference to second adjacent channels, these analog signals should be transmitted as linear vestigial sideband (VSB), with an outer vestigial sideband of approximately 500 Hz and the full sidebands folding inward. Since most of the energy in AM signals is at low frequencies, this would minimize envelope detector distortion while confining the total occupied bandwidth to just 21 kHz rather than the 30 kHz

occupied by NRSC-5. Analog listeners would tune to one of the analog signals on the adjacent channels.

(Having analog listeners retune is not without precedent. WNZK, 680/690 kHz, is a dual-frequency AM in Detroit. WNZK listeners must retune their radios between day and night. WNZK operates on 690 kHz during the daytime and 680 kHz at night.)

This approach would have several benefits. First, the interference to adjacent channels would be in the form of analog signals rather than the caustic, raucous digital signal. Second, interference to second adjacent channels would be eliminated. Third, for directional stations, the antenna pattern and its protections would be maintained for the digital signal. Fourth, the power allocated to the digital signal could be made much higher, allowing much better digital performance. Fifth, in cases of severe adjacent channel interference, one of the two analog signals could be deleted.

3. Also allow analog-only broadcasters to occupy three channels instead of one, as a means of spectral self-defense. If digital broadcasters get three contiguous channels, then it is only fair that analog broadcasters have the same amount of spectrum. For example, if an analog-only broadcaster on 830 kHz experiences IBOC interference, he could transmit additional analog signals on 820 and 840 kHz at a lower power level than his 830 kHz signal. Listeners could tune to whichever of the three frequencies suffers the least amount of interference. The outer signals on 820 and 840 kHz would again be vestigial sideband AM, however in the case of analog broadcasts, they would be folded outwards rather than inwards. In this example the 840 kHz signal would be primarily upper sideband and the 820 kHz signal would be primarily lower sideband, limited to 5 kHz of audio response with a 500 Hz vestigial sideband. The 830 kHz signal could still be transmitted with up to 10 kHz of bandwidth. The result would have the same bandwidth as NRSC-5 (30 kHz), but the nature of the adjacent channel interference generated by the two additional analog signals would be less objectionable since they would be analog.

This last suggestion may seem sarcastic and outrageous, but that is only because the whole notion of NRSC-5 is also outrageous in many ways.

The audio codec cannot be upgraded

NRSC-5 would forever limit both the AM and FM systems to a single audio codec. Audio coding technology is improving rapidly and it would be negligent to allow only one audio codec to be used, even after it is obsolete.

The modulation system cannot be upgraded

Although advances in modulation systems are not proceeding as rapidly as audio coding developments, there is still progress being made, which would be denied if only one basic modulation method is allowed.

The digital modulation system proposed is not sufficiently hierarchical

A digital modulation system should degrade gracefully in the presence of reduced signal to noise ratio, interference, etc. This is particularly important for the AM system. Yet NRSC-5 degrades abruptly, at which point it must switch to the analog signal. This characteristic illustrates that the system still needs work. The digital modulation and coding systems should include both robust and non-robust components, with a degraded minimal signal carried by the robust modulation components. It should never be necessary to revert to the analog signal, especially since the analog signal is expected to eventually disappear.

The audio codec and modulation system are secret and proprietary

Creating an FCC broadcast standard that is secret and proprietary would be unprecedented. The technical descriptions of the FCC-standardized pilot tone FM stereo system, the BTSC system, the NTSC system, and the ATSC system are all public. After the patents expire for each of these systems, they become public domain. This is not the case with the secret NRSC-5 system. Unless these systems are completely disclosed, users will be forced to pay royalties beyond the patent terms for the privilege of using a trade secret. This would be a perpetual windfall for those doing the licensing, and an ongoing burden for the public.

NRSC-5 describes the transmitted signal rather than the receiver

We are now well past the time when low-cost software-defined radios (SDRs) can be implemented for broadcast reception. The public interest demands that digital audio broadcasting be done this way. Automatic software upgrades to receivers can be performed over the air, invisibly to the consumer. This will allow improvements in audio quality, addition of multiple program streams, extension of coverage area, reduction of interference, tailoring the signal and codec characteristics to each broadcaster's needs, and additional services that cannot be foreseen at this time.

Just as open-source audio codecs have been developed under the General Public License (GPL), public domain digital broadcasting standards may also be developed which will be royalty-free for both broadcasters and receiver manufacturers. This would certainly serve the public interest better than a secret monopoly with avaricious royalties.

In the early 1980s the Commission tried a "marketplace" approach to AM stereo, allowing any kind of AM stereo signal to be transmitted. Whether this worked is open to debate, but most would admit that it failed. In any event, it was done at a time when consumer electronics technology did not support the concept of economical and accurate multisystem receivers, let alone reprogrammable receivers. That is no longer true. Reprogrammable digital signal processors have been used in broadcast radios for several years now, so the notion of a software-defined AM/FM radio has been quite feasible for years.

Conclusion and recommendation

I recommend that the Commission send the NRSC-5 proposal back to committee with the stipulation that NRSC rework the system to be fully software defined in such a way that all receivers may receive any kind of transmitted signal. This will bring competition and further much-needed improvements to digital audio broadcasting. The alternative is high costs, extensive interference, and technical stagnation.

If approved, NRSC-5 will be obsolete soon after its approval.

Sending NRSC-5 back to committee for improvements will also satisfy Microsoft's useful suggestion that the audio codec be made reprogrammable. At the same time, NRSC can make the modulation method(s) reprogrammable too.

With these improvements, if broadcasters wish to transmit the NRSC-5 signal as secretly specified today, they may do so. But if they wish to use an improved signal format, they will have that option also.

Respectfully submitted,

David L. Hershberger
P. O. Box 2163
Nevada City, California 95959-9136

dave@w9gr.com

Attachment: 1997 IEEE BTS paper

A Proposal for a Software Based
LW/MW/SW Digital Broadcast System

David L. Hershberger
Continental Electronics, Inc.
Dallas, Texas

ABSTRACT

Proposals are currently being made for digital broadcasting on the AM bands (longwave, medium wave, and shortwave). Although it would be desirable to develop a modulation and compression system which would be optimum for all users for many decades, it is unlikely that an unchanging optimum system will ever exist for all purposes and all propagation conditions.

Unlike previous standardization efforts where the broadcast signal itself was specified, it is now possible to instead standardize the receiver. The receiver would include a low cost general purpose digital signal processor (DSP). It could be programmed using a low speed ancillary data channel included in off-air signals to decode any of several different digital modulation coding and audio compression systems. Receivers would store new decoding software in nonvolatile memory and would execute it when instructed to do so by the broadcast station. These functions would be transparent to the receiver's user. New modulation and compression methods could be implemented as they are developed, avoiding premature obsolescence.

A software based receiver would allow the selection of the optimum transmission method for each station. The transmission method could change with time of day to compensate for interference and/or skywave propagation, and would allow trading off coverage area, audio quality, skywave performance, time delay, graceful degradation, etc.

The remainder of this paper proposes possible architectures for the receiver, and a packetized signaling system to control and update the receiver.

INTRODUCTION

A world consortium for digital AM radio broadcasting has been formed, known as Digital Radio Mondiale or DRM. The purpose of the DRM consortium is to develop a world digital broadcasting standard for the AM bands below 30 MHz.

(Although a misnomer, digital broadcasting on longwave, medium wave, and shortwave - the traditionally AM bands - is being called "digital AM." "Digital AM" will be used in this paper to refer to digital broadcasting below 30 MHz.)

One of the requirements specified by the DRM consortium[1] reads as follows:

"Ideally the system should be designed in order that future improvements in audio compression algorithms can be implemented at the broadcasting side. Receivers in the field do not have to be replaced when using a new algorithm."

It is the purpose of this paper to present several techniques to make the digital AM system conform to this requirement. Basically, the receiver will be specified to include a general purpose digital signal processor (DSP). The required DSP decoding software will be broadcast along with the digital audio program.

This kind of system will provide a high degree of flexibility.